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# The rapid expansion of herbicide use in smallholder agriculture in Ethiopia: Patterns, drivers, and implications

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## ABSTRACT

We use qualitative and quantitative information from a number of datasets to study the adoption patterns and labor productivity impacts of herbicide use in Ethiopia. We find a four-fold increase in the value of herbicides imported into Ethiopia over the last decade, primarily by the private-sector. Adoption of herbicides by smallholders has grown rapidly over this period, with the application of herbicides on cereals doubling to more than a quarter of the area under cereals between 2004 and 2014. Relying on unique data from a large-scale survey of producers of teff, the most widely grown cereal in Ethiopia, we find significant positive labor productivity effects of herbicide use of between 9 and 18 percent. We show that the adoption of herbicides is strongly related to proximity to urban centers, levels of local rural wages, and access to markets. All these factors have changed significantly over the last decade in Ethiopia, explaining the rapid take-off in herbicide adoption. The significant increase in herbicide use in Ethiopia has important implications for rural labor markets, potential environmental and health considerations, and capacity development for the design and effective implementation of regulatory policies on herbicides.


## 1. INTRODUCTION

Agricultural economies in developing countries have transformed rapidly over the past 50 years, as has been especially noted during the Green Revolution in Asia (Evenson and Gollin 2003; Pingali 2012). Adoption of modern inputs has played an important part in this transformation. The role of improved seeds and chemical fertilizer, as well as access to irrigation and improved water management has been well documented in increasing agricultural productivity in a large number of countries. Research on agro-chemicals, including insecticides, fungicides, and herbicides, and their role in the agricultural transformation process, however, has received relatively less attention. Yet, they could play a crucial role in modernizing farming systems.[1] A large part of the research on agro-chemicals and their increasing use has focused on the potentially adverse implications for the environment and health (Pingali 2001; Sheahan et al. 2016), with few researchers exploring the determinants of adoption of agro-chemicals and their impact on labor productivity in farming systems.

Herbicides are increasingly being adopted as a response to labor shortages in rapidly transforming economies, such as India and China. While agricultural and economic transformation is also happening in Africa (Reardon et al. 2015; Frankema 2014), it is estimated that only 5 percent of the cropped area of Africa receives applications of agro-chemicals (Gianessi and Williams 2011; Gianessi 2013). It is argued that herbicides have been underused in Africa, leading to significant productivity losses through, for example, hand-weeding being performed late or not frequently enough (Gianessi 2013). However, few authors have comprehensively examined this issue for Africa.

In this paper we examine the use of agro-chemicals in Ethiopia. Ethiopia presents an interesting case study given the dominance of smallholder agriculture in the country, as well as the rapid transformation processes that are unfolding in rural areas (World Bank 2015; Bachewe et al. 2015). Ethiopia is among those African countries in which adoption rates of agro-chemicals by smallholders are highest (Sheahan and Barrett 2014). This is surprising given the relatively small farm sizes in Ethiopia and its seeming abundance of labor. More in-depth analyses are therefore required.

Herbicide imports in Ethiopia have increased four-fold in the last decade, although from a low base, with increasing use by smallholder farmers. We observe diversification in the sources of herbicide imports. Herbicides are increasingly being imported from China and India, away from Western countries. There also is increasing importation of more expensive complete or one-pass types of herbicides, such as glyphosate. The cereal area to which herbicides were applied more than doubled over the last decade to more than a quarter of the cereal area cultivated in 2014. Herbicide use on cereals is found to significantly save on weeding, traditionally a major agricultural task. In consequence, the increased use of herbicides has important implications on labor markets in rural Ethiopia where the large majority of its population makes a living. In the research reported on here, we use a double-hurdle model from a large-scale survey of producers of teff, the most widely grown cereal in Ethiopia, to show that the adoption of herbicides is strongly related to distances to cities, rural wage levels, and access to markets. We show that all these factors have changed significantly over the last decade in Ethiopia, explaining

[1] Even in agriculture that is presumably more environment-friendly such as conservation agriculture (Vanlauwe et al. 2014; Thierfelder et al. 2015).

the rapid take-off in herbicide adoption. We further find significantly improved labor productivity because of the use of herbicides.

These findings have several important implications. First, it is usually assumed that labor is an abundant resource in rural Ethiopia and that, in consequence, technologies that are labor-saving will not be widely adopted. However, as has been shown in other areas, we find that farmers are willing to quickly adopt such labor-saving technologies if the conditions and the economics are right for doing so, even in low-income settings (Ruttan and Hayami 1984; Yang et al. 2013). Other studies, moreover, have shown that labor-requiring technologies are often not widely adopted, even in farming systems with abundant labor (Moser and Barrett 2006; Barrett et al. 2004; Vandercasteelen et al. 2013). Second, the availability of low-cost labor-substituting technologies, such as herbicides, releases labor – often of women and of youth – from agricultural tasks, with important implications for rural employment patterns and labor markets (Haggblade et al. 2017; Fox et al. 2013). Third, given the potential harm of herbicides on human health and the environment, the often deficient regulations on their proper use, and problems with how existing regulations are applied, greater attention will need to be paid to the regulatory regime for herbicides in these settings.

The structure of this paper is as follows. We discuss the data and methodology in Section 2. Background information is given in Section 3. We discuss in Section 4 trends in agro-chemical imports in general, and then herbicides in particular. Patterns in herbicide use and the link between herbicide adoption and labor productivity among smallholder farmers are explored in Sections 5 and 6, respectively. Drivers of changes in herbicides adoption are discussed in Section 7, and the last section concludes.

# 2. DATA AND METHODOLOGY

## 2.1. Data

To gather information for our study, we conducted two types of activities. First, interviews were conducted with key informants in the herbicides and agro-chemical sector between April and July 2016. Informants included representatives of the Ethiopian Institute of Agricultural Research (EIAR), the Ministry of Agriculture and Natural Resources (MoANR), private importers, the Adami Tulu Pesticide Processing Enterprise, agro-chemical retailers, cooperative unions, and farmer focus groups.

Second, we relied upon four sources of quantitative data:

1. Import data for the period 2004 to 2014 obtained from the Ethiopian Revenues and Customs Authority or downloaded from the United Nations' Comtrade webpage.[2] These data include information on quantities, country of consignment, values, and prices of imported agro-chemicals. The Ethiopian Revenues and Customs Authority dataset also collected information on the types of herbicides imported.
2. Data on agricultural production and practices collected annually through an agricultural sample survey, implemented by the Central Statistical Agency (CSA). This survey is typically fielded in more than 2,000 enumerations areas and involves a sample of more than 40,000 farmers. The sample is representative at regional and zonal levels.
3. Data collected in the Agricultural Growth Program (AGP) baseline survey. The survey was implemented in the four main agricultural regions of the country: Tigray, Amhara, Oromia, and Southern Nations, Nationalities, and Peoples (SNNP) in May 2011 and covered close to 8,000 households in 93 *woredas* (districts). The agricultural data used from the AGP survey in this analysis pertains to the 2010/11 main agricultural season.
4. Data from a survey fielded in November and December 2012 with 1,200 teff farmers in the five zones of the country with the highest commercial surplus of teff (Minten et al. 2015).

## 2.2. Methodology

To exploit the unique nature of the datasets and to address the research questions, three models were used. First, to study the impact of herbicide use on labor productivity, we used a fixed and random effect model of the following form:

[2] http://comtrade.un.org/

$$LQ_{ip} = \sum_{k=0}^{N} \beta_k X_{ip}^{k} + V_i + P_i + U_{ip} \quad (1)$$

where $LQ_{ip}$ is the logarithm of labor productivity of producer *i* on a plot *p*. $X_{ip}^{K}$ are other factors that influence teff labor productivity, including soil type, plot slope, seed type, altitude, and fertilizer. $V_i$ is an producer specific effect, $P_i$ is a plot specific effect, while $U_{ip}$ is a stochastic error term. Similar approaches have been used in other studies, such as Dercon and Christiaensen (2011) and Minten et al. (2015).

Second, to study the possible impacts of adopting herbicide on labor productivity, we also employ different matching techniques that rely on likelihoods from respective logit regressions (Caliendo and Kopeinig 2008). As farmers that apply herbicide may be distributed across surveyed areas in a non-random way, comparing herbicide users (adopters) with non-adopters might yield biased results due to unobserved differences between the two groups. Matching the two groups using a large set of observable variables allows us to control for such differences. We use matching techniques based on the extent of covariate balance that results from matching, and then look at the impact of herbicide application on labor productivity.

Third, to study factors determining the decision and the amount of herbicide use, we employ a double-hurdle model consisting of three components: (i) value of observed herbicide, (ii) the participation equation, and (iii) the amount equation. Following Jones (1989), the three components can be represented as:

(i) Observed spending on herbicide:

$$Y = d.y^{**} \quad (2)$$

(ii) The first hurdle examines whether a farmer chooses to adopt the use of herbicides:

$$W = \alpha' Z + u, \quad \text{where } u \sim N(0,1) \quad (3)$$

$$d = \begin{cases} 1 & if\ w > 0 \\ 0 & otherwise \end{cases}$$

(iii) The second hurdle considers for adopting farmers the amount or value of herbicides used:

$$y^{*} = \beta' X + v, \quad \text{where } v \sim N(0, \sigma^2)$$

$$y^{**} = \begin{cases} y^{*} & if\ y^{*} > 0 \\ 0 & otherwise \end{cases} \quad (4)$$

where *Z* and *X* represent controls that affect the participation and quantity decisions, and $u$ and $v$ are additive disturbance terms which are randomly distributed with a bivariate normal distribution. A positive level of herbicide use $Y$ is observed only if the farmer is a potential user ($d = 1$) and actually spends money on herbicide ($y^{**}$).[3] The variance of the error terms is specified as a function of a set of continuous variables, as in equation (5) below, in order to address the possible presence of heteroscedasticity:

$$\sigma_i = \exp(Z_i' h) \quad (5)$$

where $Z_i$ is a vector of continuous variables included in *X* or $Z_i \in X$ and $h$ is a conformable vector of coefficients. Representing no spending on herbicides as 0 and positive herbicide values as >0, the likelihood function for the full double-hurdle model with heteroscedasticity correction and independent error terms can be written as:

$$L = \prod_0 [1 - \Phi(\alpha' z)\, \Phi(\beta' x)/\sigma i] \prod_{>0} [\Phi(\alpha' z) \frac{1}{\sigma i} \phi(\frac{yi - \beta' x}{\sigma i})] \quad (6)$$

where $\Phi(.)$ denotes (univariate or multivariate) standard normal cumulative density function and $\phi(.)$ is the univariate standard normal probability density function. Maximization of the likelihood function of (6) gives consistent estimates of the parameters of the latent equations. This model hypothesizes that the participation and the amount decisions are made separately, and that there is a feedback effect from the level of use to the participation decision. Marginal effects can be obtained by differentiating the estimates (at relevant sample mean) with respect to the corresponding variable of interest.

[3] The technique relies on two crucial assumptions about: (a) the level of independence between the residuals in the two equations, and (b) whether the participation decision dominates the quantity decision. Given that we are modeling actual (instead of potential) herbicide use, dominance applies and is less likely to be a latent positive expected herbicide use. This means that we model the marginal effect of different covariates on actual herbicide use. Hence, we are interested in E[y|Z, X] instead of E[y**|Z, X], justifying the use of a double-hurdle model rather than similar techniques, such as Heckman's selection model (Croppenstedt et.al. 2003; Rude et.al. 2014).

# 3. OVERVIEW OF ETHIOPIA'S AGRICULTURE AND HERBICIDE POLICIES AND INSTITUTIONS

Agriculture is the most important sector by any measure in Ethiopia. On average, it accounted for 47 percent of the real GDP over the period between 2004 and 2014 and was the largest contributor to GDP until 2010/11, when the national value-added of the services sector first exceeded that of agriculture (Bachewe et al. 2015). Agriculture employs more than three-quarters of all workers in the country. Over the last decade, grains on average accounted for about 96 percent of the total cropped area. In particular, nearly three quarters of the area was covered by the five most important cereal crops in Ethiopia: teff, barley, wheat, maize, and sorghum. Smallholder farmers dominate the use of agricultural land, comprising 94 percent of total land cultivated in 2013/14. Absolute increases in the number of farmers nationally has led to a decline in the average landholding size by 1.4 percent over the last decade. Average farm size was 0.84 hectares in 2013/14. However, the use of chemical fertilizer and improved seed more than doubled over the last decade (but starting from a low base), leading to relatively higher output per farm (Bachewe et al. 2015).

With respect to agro-chemicals, in line with potential health and environmental risks associated with their handling (e.g. Pingali 2001), a rather strict regulatory framework has been established in Ethiopia (See Annex 1). The public sector continues to play a central role in agricultural input markets in Ethiopia (Spielman et al. 2010), but the share of agro-chemicals distributed by the public sector is much lower relative to public sector involvement in inorganic fertilizer and improved seed distribution. There are three public enterprises active in the distribution of agro-chemicals in the country.

1. The first is the Adami Tulu Pesticide Processing Share Company (ATPPSC), a government-owned enterprise importing, distributing, and formulating agro-chemicals. ATPPSC formulates liquid, powder, and dust insecticides locally. However, all the herbicide it distributes is imported.[4] Between 2010 and 2014, herbicides constituted about 65 percent of ATPPSC's total pesticide imports and distribution. Of its herbicides imports between 2010 and 2014, about 70 percent were 2-4-D types while in 2015, almost 100 percent of its herbicide imports were 2-4-D.[5]
2. The second is the Agricultural Inputs Supply Enterprise (AISE), which is accountable to the Ministry of Agriculture and Natural Resources (MoANR). Since its establishment in 1985, AISE has been buying and distributing agricultural inputs, including fertilizers, farming chemicals, seeds, and plant and animal medicines and vaccines. AISE itself imported 2-4-D until 2013, after which it has been buying 2-4-D from ATPPSC. Since 2013, AISE has directly imported the 'Pallas' brand of herbicide.[6] It distributes these inputs to farmers through its 22 warehouses in Addis Ababa, Amhara, SNNP, Oromiya, Tigray, and Benishangul-Gumuz regions.
3. The third public enterprise is the Oromiya Agricultural Cooperatives Federation that coordinates about 62 cooperative unions in Oromiya region. This federation serves cooperative unions only. The unions in turn distribute the agro-chemicals to their primary cooperatives which, in turn, provide the products to local farmers, both cooperative members and non-members.[7]

However, the majority of herbicides available in Ethiopia are imported and distributed by the private sector. Private enterprises that import such products are responsible for registering and certifying the herbicides they import. Registration requires efficacy tests by a national Pesticide Registration Committee, which is hosted by the Ethiopian Institute of Agricultural Research (EIAR). The importers typically sell their products to government enterprises and private wholesalers in major cities such as Addis Ababa, Adama, Bahir Dar, and Mekelle. The latter then distribute to private retailers that sell the products to farmers in rural areas. Private enterprises with current registrations for specific brands do not need to directly

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[4] Regulation in Ethiopia deem the raw materials of herbicides to be too flammable and toxic to transport, handle, and formulate safely. In consequence, ATPPSC primarily repacks herbicides, importing finished products in 1000 liter containers, for example, and repacking them into smaller one or five liter containers.

[5] According to ATPPSC's market share assessment, it accounts for about 25 percent of the total 2-4-D supply in the country. Its main customers are government agricultural bureaus (mainly the Agricultural Inputs Supply Enterprise), private retailers, and commercial farmers. It distributes pesticides through its two offices in Addis Ababa and Ziway, where it charges a fixed price for a given type of pesticide.

[6] AISE imports 'Pallas' brand with permission from CHEMTEX, a private pesticide company in Ethiopia with a registered license for marketing 'Pallas' in Ethiopia. This is in line with regulations that require any government or private party that wants to import such registered products to obtain permission from the registered company, with the registered company obtaining a commission from the importer based on the quantity of the product imported.

[7] The Federation has a couple of advantages over other distributors. First, it has better access to rather scarce foreign currency in the form of credits through commercial banks. Second, unlike private sector firms that have to advertise to introduce their products to farmers, the Federation is a better trusted organization and can more easily convince farmers about the value of agro-chemicals than can private sector distributors.

import the herbicides themselves. They often give permission of import to eligible importer(s) for a pre-specified commission per volume of import. As of June 2016, only 28 of the 53 registered importers of pesticides had registrations for herbicides. The 28 registered companies overall have more than 100 herbicide brands registered, out of which nine had registrations for more than three brands.[8] Although data are unavailable, experts at the EIAR and at the MoANR stated that the number of registered importers of herbicides increased significantly over the last decade.

According to our focus group discussions with key stakeholders in agro-chemical value chains, along with increasing imports and wider distribution of herbicides in the country, there are reported issues of poor herbicide quality, adulteration, and subsequent health risks that should be better monitored. A range of problems have been identified:

- Differences are sometimes found between the products registered for importation and those that actually are then imported.
- Currently there are no strict supervision and control mechanisms in place once an herbicide is imported into the country. Consequently, counterfeit products are sometimes found in the market.
- Commercial growers are sometimes exempt from registration as importers of pesticides, but might sell some of their leftovers at lower prices in the market, creating unfair competition.
- In some cereal growing areas, herbicides are being distributed by unqualified individuals with minimal training on the safe handling of herbicides[9].
- Safe use of herbicides is not always followed. While extension agents and farmers are increasingly trained to wear appropriate clothing when applying agro-chemicals and pamphlets explaining this are widely available, such practices, however, are not always adhered to and the application of herbicides is often done without proper protection. This might have health implications for those farmers that do not follow proper practicies for safe herbicide use (Sheahan et al. 2016)[10].

Overall, stakeholder interviews and anecdotal evidence suggest that adulteration of herbicides at retail level is becoming an increasing problem. The regulatory authorities, such as the Regulatory Directorate at MoANR, do not yet have adequate capacity and resources at their disposal to ensure proper design and implementation of needed regulatory policies for herbicides, specifically, and agro-chemicals, in general. Further, there are significant knowledge gaps on the health effects of some of the herbicides used in Ethiopia. However, caution is required as to the health significance of these knowledge gaps, as no solid data on this issue was provided by our key informants.

## 4. PATTERNS IN HERBICIDE IMPORTS

No herbicides are produced in Ethiopia; all agro-chemicals are imported. Analyzing customs data therefore helps to reveal patterns of herbicide use. In this section, we analyze these patterns using data from Comtrade and from the Ethiopian Revenues and Customs Authority. Despite slight differences, both datasets show significant increases in imports into Ethiopia over the last decade of pesticides and, in particular, herbicides. Figure 4.1 illustrates the trend in value and composition of agro-chemical imports over the last decade. We see that imports of agro-chemicals increased fivefold, from just below 20 million USD in 2005 to over 100 million USD in 2015. The biggest share of agro-chemical imports are insecticides, making up 52 million USD in 2015. The second most important agro-chemicals are herbicides[11]. The value of herbicide imports quadrupled over the last decade, from about 5 million USD to about 20 million USD. Most of the insecticides are used in the flower industry. However, herbicides are not commonly used in that sub-sector.

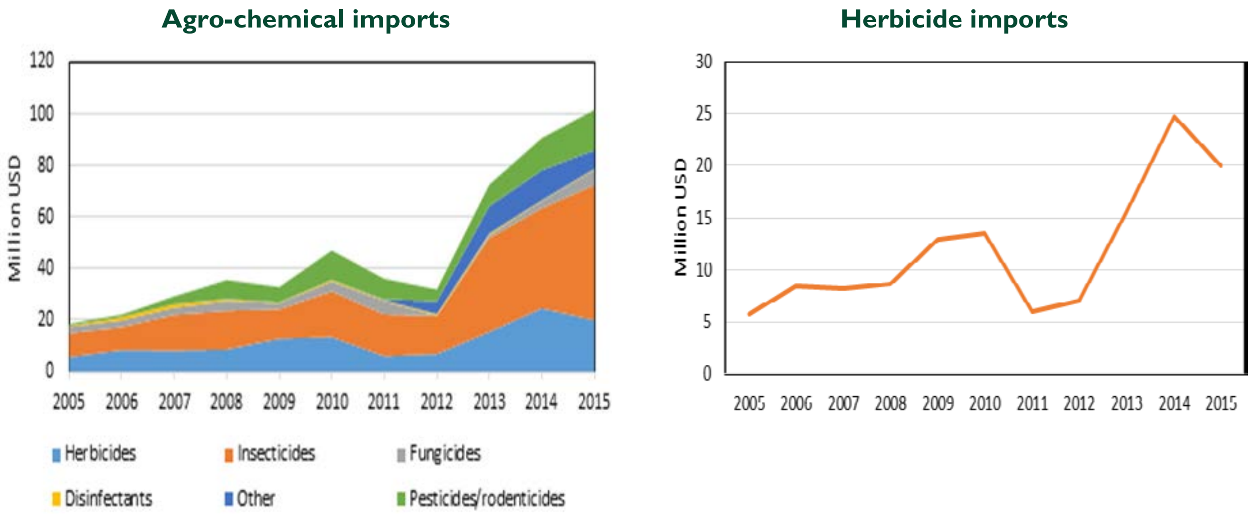
[8] The most important private herbicide importers include General Chemical & Trading PLC, Syngenta Agroservices Ag. Ethiopia, Chemtex PLC, Lions International Trading PLC, Makobu Enterprises, Girma Teferi, Wondimagegn, B-Nyse General Trading PLC, Mekamba PLC, and Rangvet PLC.

[9] The requirement is that a herbicide distributor should be an agronomist with at least 5 years of experience or should employ an individual with such qualifications.

[10] There are further significant knowledge gaps on the health effects of some of the herbicides, even if applied properly (Grossman 2015).

[11] However, given that insecticides are much more expensive per unit than herbicides, in terms of quantity, herbicides would likely be the most important.

**Figure 4.1: Agro-chemical and herbicides imports in Ethiopia, by value, 2005 to 2015**




Source: Based on data from Comtrade (2016).

Table 4.1 shows the evolution of the type and origin of herbicides imported over time. 2-4-D is the most important herbicide imported into the country in terms of both value and quantity.[12] While the value of 2-4-D imports increased by 160 percent over the last decade, its share of the total value of herbicides imports is declining. 2-4-D made up 41 percent of the value of all herbicides imports in 2015. This compares to 78 percent in 2005. Table 4.1 illustrates that 2-4-D has a lower price relative to other types of herbicides. Since 2-4-D kills only broadleaf weeds, weeding is, therefore, often still required after the use of 2-4-D. Therefore, other wider-ranging herbicides are increasingly being used.

**Table 4.1: Source of herbicide, based on country of consignment, 2005 and 2015**

| | 2005 | | | 2015 | | |
|---|---|---|---|---|---|---|
| | USD (millions) | Share | Price (USD/liter) | USD (millions) | Share | Price (USD/liter) |
| *Country of consignment* | | | | | | |
| China | 0.28 | 8.9 | 2.4 | 7.58 | 47.5 | 3.0 |
| India | 0.00 | 0.0 | 2.3 | 2.31 | 14.5 | 3.9 |
| Switzerland | 0.06 | 2.0 | 9.4 | 2.23 | 14.0 | 5.9 |
| Belgium | 0.26 | 8.3 | 9.1 | 1.25 | 7.9 | 11.9 |
| France | 0.18 | 5.8 | 28.7 | - | - | - |
| Germany | 1.16 | 36.4 | 2.8 | 1.20 | 7.5 | 23.3 |
| Others | 1.23 | 38.6 | 4.8 | 1.37 | 8.6 | 13.7 |
| Total | 3.19 | 100.0 | 6.6 | 16.00 | 100.0 | 7.4 |
| *Herbicide type* | | | | | | |
| 2-4-D | 2.50 | 78.2 | 3.6 | 6.57 | 41.2 | 3.7 |
| Glyphosate | 0.10 | 3.2 | 4.1 | 3.61 | 22.7 | 4.1 |
| Others | 0.59 | 18.6 | 13.8 | 5.77 | 36.2 | 11.5 |
| Total | 3.19 | 100.0 | 6.6 | 16.00 | 100.0 | 7.4 |
| *Unit price evolution* | | | | | | |
| a. 25th percentile | | | 2.8 | | | 2.5 |
| b. Median | | | 3.4 | | | 4.4 |
| c. 75th percentile | | | 5.7 | | | 7.4 |
| d. Variation (measured by c – a) | | | 2.9 | | | 4.9 |

Source: Based on data from Ethiopian Revenues and Customs Authority (2005-2015)

[12] 2-4-D is one of the oldest and most widely used herbicide in the world and has been commercially available since 1945. It is now produced by many chemical companies since the patent on it has long expired.

Brands of glyphosate, a broad-spectrum herbicide, made up only 3 percent of all imports in 2005, while their share increased to 23 percent in 2015. Glyphosate is applied in crop agriculture before plants are sown, killing all weeds. It therefore considerably reduces the labor required for land preparation. It is especially used in perennial crops and under minimal tillage practices (Temesgen 2015). More expensive and more complete second-generation herbicides to glyphosates are also being used. These include Pallas (a product of Dow Chemicals), Atlantis (Syngenta), and others. These herbicides are more expensive and considered one-pass solutions as they not only kill broadleaf weeds but also kill grass-like weeds.[13] While the previously released Topik (also from Syngenta) kills grass weeds, Pallas and Atlantis can kill all broadleaves as well as small and broad grass-like weeds, justifying the higher price of the latter herbicides.

Table 4.1 further illustrates that the countries from which herbicides have originated changed considerably in the last decade. While the share from China and India was small in 2005, they since have become dominant sources. This could be because the patent rights of the original manufacturers of a number of herbicides, notably 2-4-D and glyphosate, have expired. These herbicides are now increasingly being produced in China and India. The increasing diversification in herbicide imports is further illustrated by the unit price evolution of herbicides over time shown at the bottom of Table 4.1. Median prices have risen slightly in nominal terms, from 3.4 USD/lt in 2005 to 4.4 USD/lt in 2015. However, the prices of the lower-priced herbicides (the 25th percentile) has decreased in nominal terms, from 2.8 to 2.5 USD/lt. This is in contrast with prices of more expensive herbicides (75th percentile), which increased in nominal terms by 30 percent, from 5.7 to 7.4 USD/lt. Overall, the unit price variation between the 25th and 75th percentiles increased from 2.9 USD/lt in 2005 to 4.9 USD/lt in 2015, seemingly consistent with the increasing diversification in types of herbicides imported and used in Ethiopia.

## 5. PATTERNS OF HERBICIDE USE BY SMALLHOLDERS

In this section, we analyze patterns in pesticides use of smallholder farmers focusing on the types of crops and the size of farms on which these inputs are applied, the dynamics of use over time, and the importance of the public sector in herbicides distribution. First, we look at the importance of different types of herbicide distributors for these smallholders. In the AGP baseline survey, farmers were asked from whom they bought agro-chemicals and other modern inputs, such as chemical fertilizers. Table 5.1 shows that most of the chemical fertilizer and improved seeds distribution is assured by the government through its cooperative networks. The distribution of agro-chemicals, in contrast, is mostly in the hands of private distributors, with the private sector being responsible for about two-thirds of their distribution. The private sector plays an even larger role in the distribution of herbicides – close to 70 percent of farmers reported that they obtained the herbicides they used through a private channel. Only 27 percent of farmers obtained herbicides from government and related sources, such as local cooperative and government extension agents (Table 5.1).

**Table 5.1: Source of agro-chemicals purchased by smallholder farmers**

| Source | Herbicides | Insecticide | Fungicides | Chemical fertilizer | | Improved seed |
|---|---|---|---|---|---|---|
| | | | | DAP | Urea | |
| Government related | 27.0 | 31.4 | 43.3 | 83.3 | 84.8 | 87.6 |
| Private | 67.7 | 64.0 | 51.1 | 13.9 | 11.9 | 6.2 |
| Other farmers | 3.8 | 2.7 | 2.7 | 1.1 | 1.0 | 2.3 |
| Development organizations/church | 0.3 | 0.7 | 1.6 | 1.4 | 1.9 | 2.4 |
| Others | 1.1 | 1.2 | 1.4 | 0.3 | 0.4 | 1.4 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Source: Authors' calculation based on the 2011 AGP Baseline Survey dataset

Second, we look at use of herbicides on specific crops, relying on AGP survey data, as summarized in Table 5.2. Two main points emerge. First, herbicides are the most used pesticides by smallholder farmers. Of the area cultivated, 23 percent was exposed to herbicide use. This compares to one percent for insecticides and two percent for fungicides. Second, when we examine the type of crops on which herbicides are applied, they are especially used on cereals – on an estimated

[13] Prices in the middle of 2016 were around 90 Birr per liter (and per hectare) in the case of 2-4-D. Pallas was being sold more than 10 times higher at 1,100 Birr/ha. The cost of Topik was around 600 Birr/ha.

36 percent of the cereal area. Among cereals, herbicide use is most prevalent in teff and wheat, the most commercialized crops in Ethiopia.[14] Herbicides were used on 46 and 60 percent of the area under these crops, respectively.

**Table 5.2: Share of households and share of crop area where pesticides are used in high-potential areas**

| | Share of households applying* | | | Share of crop area to which was applied | | |
|---|---|---|---|---|---|---|
| **Crop/Farm size** | **Herbicide** | **Insecticide** | **Fungicide** | **Herbicide** | **Insecticide** | **Fungicide** |
| ***By crop*** | | | | | | |
| All crops | 14.6 | 1.7 | 1.0 | 23.2 | 1.0 | 1.7 |
| Cereals | 27.2 | 1.3 | 1.3 | 35.8 | 1.2 | 1.5 |
| Teff | 40.6 | 0.7 | 0.2 | 45.8 | 0.3 | 0.8 |
| Barley | 29.5 | 1.0 | 0.7 | 39.2 | 0.6 | 0.8 |
| Wheat | 49.3 | 1.5 | 5.0 | 59.9 | 5.0 | 1.5 |
| Maize | 6.6 | 1.7 | 0.3 | 15.2 | 0.3 | 2.1 |
| Sorghum | 9.6 | 2.0 | 0.5 | 16.9 | 0.4 | 2.6 |
| Pulses | 1.5 | 2.9 | 0.4 | 1.7 | 0.3 | 3.9 |
| Oil-seeds | 2.2 | 0.4 | 0.1 | 4.4 | 0.1 | 0.4 |
| Vegetables | 0.8 | 0.3 | 1.6 | 6.6 | 8.2 | 0.3 |
| Root crops | 1.3 | 6.9 | 3.8 | 1.3 | 4.2 | 6.2 |
| Fruit crops | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Chat | 0.1 | 10.7 | 1.3 | 0.0 | 1.9 | 14.9 |
| Coffee | 0.6 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 |
| Enset | 0.6 | 0.2 | 0.3 | 0.2 | 0.1 | 0.0 |
| All other crops | 9.1 | 0.9 | 0.4 | 11.3 | 0.5 | 1.0 |
| ***By farm size*** *(average crop area in parentheses)* | | | | | | |
| Quintile 1 (0.2 ha) | 18.6 | 3.3 | 2.7 | | | |
| Quintile 2 (0.5 ha) | 31.3 | 5.6 | 4.0 | | | |
| Quintile 3 (0.9 ha) | 38.0 | 6.4 | 4.0 | | | |
| Quintile 4 (1.5 ha) | 48.0 | 4.8 | 2.3 | | | |
| Quintile 5 (3.0 ha) | 53.4 | 7.4 | 2.9 | | | |
| All (1.1 ha) | 36.8 | 5.4 | 3.2 | | | |

Source: Authors' calculation based on the 2011 AGP household dataset

* Weighted by crop area

Third, the bottom panel of Table 5.2 examines agro-chemical adoption patterns by farm size. Households in the AGP dataset were ranked by land size quintiles. We note that pesticide use is significantly lower for the smallest farm-size quintile. Considering herbicide use in particular, 38 percent of farm households use herbicides, but there is a consistent increase in prevalence of use from the lowest quintile to the highest quintile. The share of farmers that use herbicides in the lowest quintile is only 18 percent, but this rises to 53 percent for the largest farm-size quintile.

**Table 5.3: Cropped area to which pesticides were applied nationally, by crop, percent of crop area, 2004/05 and 2014/15**

| Crop | 2004/05 | 2014/15 |
|---|---|---|
| All crops | 12.1 | 22.3 |
| Cereals | 16.7 | 29.5 |
| Teff | 24.5 | 45.7 |
| Wheat | 38.0 | 52.4 |
| Pulses | 0.8 | 7.3 |
| Oilseeds | 1.1 | 4.0 |
| Vegetables | 2.3 | 4.0 |
| Root crops | 3.0 | 17.0 |

Source: Authors' computations using CSA annual reports (CSA Volumes I and III 2005-2014).

[14] Based on the data from the Central Statistical Agency (CSA), the value of commercial surplus of all cereals was estimated at 1.48 billion USD in 2013/14. Of this, teff and wheat were most important with 0.75 billion USD and 0.29 billion USD commercial surplus, respectively.

Fourth, we look at dynamics in the adoption of pesticides by smallholders. For this, we use national data from the Central Statistical Agency (CSA), a representative survey of smallholders with less than five hectares of land. The results in Table 5.3 show that the proportion of cultivated area on which pesticides (mostly herbicides) were applied, increased for all crops from 12 percent in 2004/05 to 22 percent in 2014/15. We also note that there is more agro-chemical use on cereals than on other crops. Pesticide use increased in cereals by 76 percent between 2004/05 and 2014/15, from 16.7 percent of the cereal area in 2004/05 to 29.5 percent in 2014/15. The absolute cereal area to which pesticides were applied increased from 1.3 to 3.0 million hectares, or by 135 percent, between 2004/05 and 2014/15.

In brief, the analysis above shows that there has been increasing use and adoption of herbicides in the country. While 2-4-D has been the most widely used herbicide, we observe the recent take-up of second-generation herbicides that deal with a wider range of weeds. We also note the emergence of India and China as dominant sources of herbicides. We further have found that the private sector has been instrumental in this growth in herbicide use and that smallholders - especially those with relatively larger farm sizes - have quickly adopted herbicides. We estimate that herbicide is used on more than a quarter of the area under cereals, and even more so on the commercial cereals, such as teff and wheat. In the analysis below, we quantify the different factors associated with the increasing adoption of herbicides and look at the impact of herbicides on labor productivity.

# 6. LABOR PRODUCTIVITY EFFECTS OF HERBICIDES

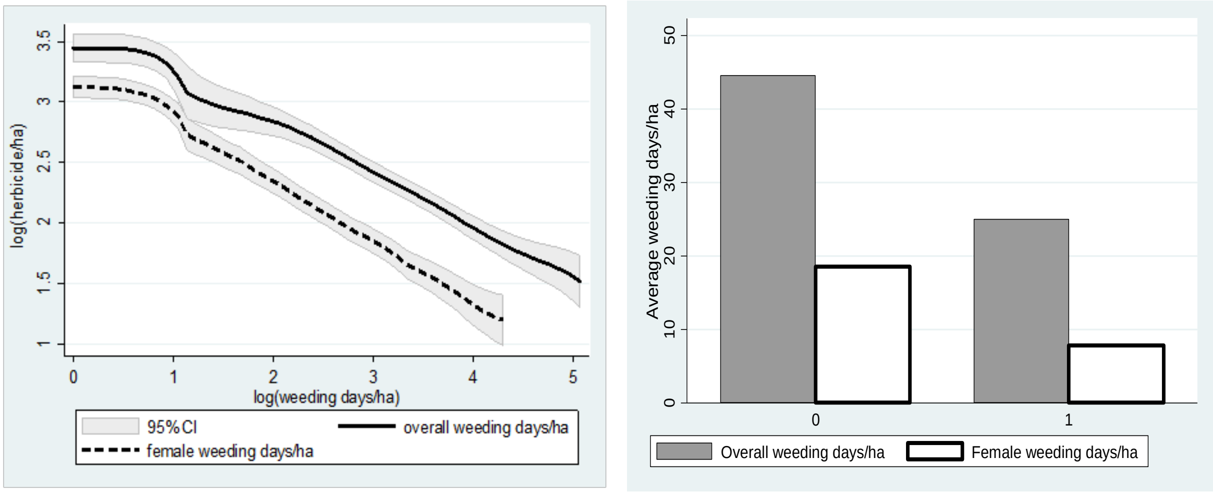
Herbicides mainly save on weeding effort. Figure 6.1 illustrates the strong negative association between weeding labor and adoption and level of use of herbicides. Using non-parametric regressions, the graph on the left in Figure 6.1 displays the per hectare value of herbicide use and the amount of weeding labor. Farmers with higher spending on herbicides employ relatively less weeding labor. The dashed line further shows how the increasing application of herbicide reduces the time women spent on weeding. Nonetheless, weeding labor does not drop completely to zero, indicating that even after using 2-4-D, weeding is still required to remove grass-like weeds.

The figure on the right of Figure 6.1 illustrates that non-adopters use on average 45 person days per hectare for weeding labor, while adopters, even after applying herbicides, use 25 person days. The substantial reduction in labor, however, indicates that farmers are substituting weeding labor with herbicides. A similar relationship is observed between herbicide use and female weeding labor – non-adopters of herbicide on average use 19 woman-days per hectare, while adopters only use 8 woman-days per hectare for weeding. Liberating women of weeding tasks may therefore have considerable positive implications on the workload of rural women, and thus on the welfare of rural households in general, since it affects the time allocated for housekeeping, cooking, childcare, and other activities.

**Figure 6.1: Teff production – association between use of herbicide and weeding labor (overall and female labor only)**

Relationship between the value of herbicide and the amount of weeding labor used

Amount of weeding labor used by non-adopters (left bars) and adopters (right bars) of herbicide




Source: Authors' calculation based on the 2012 teff producers' survey

**Table 6.1: Association of herbicide use with teff labor productivity using fixed and random effect models**

| | | Fixed Effects | | | | Random Effects | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Weeding labor productivity† | | Total labor productivity†† | | Weeding labor productivity | | Total labor productivity | |
| Variables | Unit | Coef. | t-stat | Coef. | t-stat | Coef. | z-stat | Coef. | z-stat |
| Used herbicides | =1 if yes | 0.18**** | 6.97 | 0.09*** | 5.98 | 0.27**** | 3.92 | 0.12 | 1.33 |
| Area of plot | log(ha) | 0.30**** | 5.21 | 0.29*** | 6.07 | 0.29*** | 4.22 | 0.25*** | 5.24 |
| DAP use | log(kg) | 0.03 | 0.55 | 0.40 | 0.71 | 0.05 | 1.09 | 0.06* | 1.65 |
| UREA use | log(kg) | 0.03 | 0.48 | -0.01 | -0.13 | 0.09 | 1.65 | 0.09** | 1.68 |
| Gender of head | =1 if male | | | | | -0.13*** | -2.99 | 0.01 | 0.14 |
| Head has some education | =1 if yes | | | | | 0.08*** | 3.78 | 0.10*** | 3.49 |
| Household (HH) size | log(number) | | | | | -0.21*** | -3.80 | -0.19*** | -3.62 |
| Share of children in HH | Share | | | | | 0.00** | 2.54 | 0.00 | 1.57 |
| Share of elderly in HH | Share | | | | | 0.00 | 0.68 | -0.00 | -0.12 |
| Selected as model farmer | =1 if yes | | | | | 0.03 | 0.55 | 0.05 | 1.43 |
| Land owned | log(ha) | | | | | -0.03 | -0.87 | -0.04 | -1.26 |
| Altitude | log(meter) | | | | | -0.65 | -1.32 | -0.04 | -0.11 |
| Additional controls for: | | | | | | | | | |
| Soil easy to plow | | Yes | | Yes | | Yes | | Yes | |
| Planted teff last year | | Yes | | Yes | | Yes | | Yes | |
| Rain and pest patterns | | Yes | | Yes | | Yes | | Yes | |
| Color of soil | | Yes | | Yes | | Yes | | Yes | |
| Slope of plot | | Yes | | Yes | | Yes | | Yes | |
| Organic fertilizer applied | | Yes | | Yes | | Yes | | Yes | |
| Color or seed | | Yes | | Yes | | Yes | | Yes | |
| Constant | | -0.95*** | -6.91 | -2.12*** | -20.15 | 4.44 | 1.24 | -1.79 | -0.62 |
| Number of observations | | 2,2 | | 2,484 | | 2,379 | | 2,484 | |

Source: Authors' calculation based on the 2012 teff producers' survey

†: log(production/weeding days); ††: log(production/total labor days). Coefficients with ***, **, and * are significant at 1, 5, and 10 percent, respectively.

We measure the association of herbicide use on labor productivity in a multivariate regression framework using fixed-effect and random-effect models.[15] In each of these specifications, we conduct the analyses using two measures of labor use as dependent variables. As herbicide is primarily used to control weeds, the first set of analyses uses as the dependent variable productivity of weeding labor. The second set of analyses uses as the dependent variable productivity of total labor used in teff production, which includes all activities such as tilling, weeding, harvesting, and post-harvesting activities. The results presented in Table 6.1 indicate that, when we look at weeding labor only, herbicide use results in an 18 percent increment in labor productivity. Looking at all labor, herbicide use leads to a 9 percent increment in overall labor productivity for the preferred fixed-effects model.

Additionally, we conduct different propensity score matching exercises. The results of these exercises are presented in Table 6.2. The third and fourth columns of the table indicates that herbicide application results in significantly larger labor productivity. The four matching techniques employed imply that herbicide adoption leads to a considerable increase in weeding labor productivity, which, depending on the technique used, ranges from between 43 to 51 percent. Herbicide adoption results in an increase in overall labor productivity of between 12 and 18 percent. It is important to point out that these productivity improvements are gross measures only – net gains should also consider the cost of acquiring herbicides.

[15] The Hausman test is in favor of fixed effects specification at 1 percent level of significance with $\chi^2_{29} = 35.63$.

**Table 6.2: Association of herbicide use with teff labor productivity using matching techniques**

| Variables [applying herbicide=1, not applying=0] | | Dependent Variables: Weeding labor productivity | Dependent Variables: Overall labor productivity |
|---|---|---|---|
| **Matching Regression** | | | |
| ATET - Nearest neighbor matching | Coef. | **0.431** | **0.123** |
| | z-value | 9.05 | 3.32 |
| ATET- Kernel matching | Coef. | **0.508** | **0.176** |
| | z-value | 10.56 | 4.47 |
| ATET - Regression adjustment matching | Coef. | **0.468** | **0.171** |
| | z-value | 11.87 | 5.67 |
| ATET - IPW matching | Coef. | **0.473** | **0.175** |
| | z-value | 11.82 | 5.69 |

Source: Authors' calculation based on the 2012 teff producers' survey

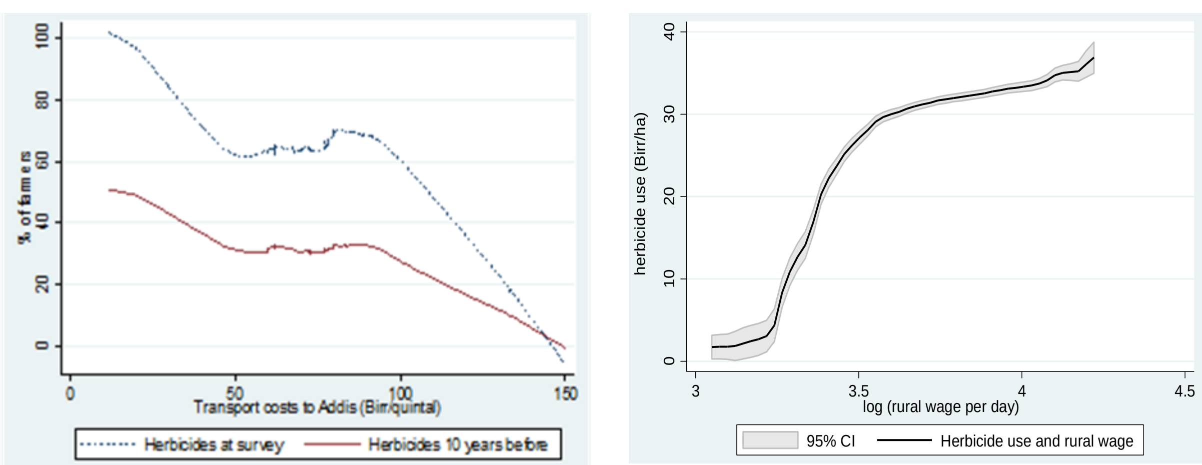
Note: Robust standard errors used for all matching exercises. Bold figures: significant at 5% significance level.

# 7. ADOPTION AND DRIVERS FOR EXPANSION

Herbicide use leads, on average, to significant improvements in labor productivity, especially for weeding labor. However, there is heterogeneity in adoption and a number of factors might play a role in non-universal adoption. In this section we look at factors associated with adoption and then try to identify drivers for the increasing adoption of herbicides. We use two criteria to identify the drivers for the increasing adoption herbicides over the last decade. First, these factors need to be linked with significantly greater adoption, and second, they need to show major changes over the last decade.

We first look at the non-parametric results of some likely associated factors that showed major change over the last decade. In the teff survey, farmers were asked whether they used herbicides 10 years prior to the survey period (late-2012) and if they were using herbicides at the time of the survey. Figure 7.1 below illustrates how adoption patterns vary over time and space. We see significantly higher adoption rates in areas that are better connected to urban centers at the time of the survey, as well as 10 years earlier. We also note a significant shift in adoption patterns over time, even if access costs did not change. For the least remote farmers, adoption rates of herbicides, almost exclusively 2-4-D at the time of the survey, doubled from half of the farmers to all farmers. For the most remote farmers, little change is noted. Overall, this graph illustrates the dynamics in herbicides adoption, as well as the important impact of market access. The graph on the right in Figure 7.1 also shows, using non-parametric regressions, the strong linkages of herbicides use with prevailing wage levels in the villages surveyed.

**Figure 7.1: Herbicides adoption and its link with transport cost to cities (left figure) and wage levels (right figure)**




Source: Authors' calculation based on the 2012 teff producers' survey

**Table 7.1: Analysis of the factors associated with the adoption of herbicide and the amount of herbicide used**

| | | Decision to use (yes/no) herbicide | | Amount (value) of herbicide used | | Average (APE) | |
|---|---|---|---|---|---|---|---|
| **Variables** | **Unit** | **Coef.** | **t-value** | **Coef.** | **t-value** | **Coef.** | **z-value** |
| Transport cost to Addis | log(birr/qt) | -0.44*** | -4.61 | -2.31** | -2.16 | -1.45** | -2.08 |
| Daily wage rate (village level) | log(birr/ person/day) | 2.62*** | 9.28 | 9.71*** | 3.00 | 6.13*** | 3.13 |
| Distance to all-weather road | log(mn) | -0.02 | -1.04 | -0.54 | -1.55 | -0.34 | -1.47 |
| Distance to nearest cooperative | log(mn) | 0.07 | 1.22 | -0.26 | -0.44 | -1.67 | -0.44 |
| Distance to nearest agro-dealer | log(mn) | -0.17*** | -2.94 | 1.49*** | 2.62 | 0.94** | 2.38 |
| Visited by extension agent | =1 if yes | 0.06 | 0.61 | -0.59 | -0.48 | -0.37 | -0.46 |
| Gender of head | =1 if male | -0.68 | -2.78 | 2.84 | 1.70 | 1.79 | 1.53 |
| Head has some education | =1 if yes | -0.00 | -0.04 | -1.83* | -1.77 | -1.15* | -1.76 |
| Size of the HH | log(number) | -0.09 | -0.75 | -1.96 | -1.43 | -1.23 | -1.47 |
| Share of children in HH | Share | 0.01*** | 3.15 | 0.05* | 1.75 | 0.03* | 1.74 |
| Share of elders in HH | Share | -0.01 | -0.85 | -0.11 | -1.50 | -0.07 | -1.45 |
| Selected as model farmer | =1 if yes | -0.17** | -2.02 | -1.68* | -1.65 | -1.06 | -1.62 |
| Land owned | log(ha) | 0.58*** | 8.62 | 1.59** | 2.33 | 1.01** | 2.37 |
| Altitude | log(meter) | -2.08*** | -5.25 | 3.91 | 1.17 | 2.47 | 1.09 |
| Assets | log(birr) | 0.20*** | 6.91 | 0.69** | 1.97 | 0.44* | 1.87 |
| Additional controls for: | | | | | | | |
| Soil easy to plow | | Yes | | Yes | | | |
| Planted teff last year | | Yes | | Yes | | | |
| Rain and pest patterns | | Yes | | Yes | | | |
| Color of soil | | Yes | | Yes | | | |
| Slope of the plot | | Yes | | Yes | | | |
| Color of seed | | Yes | | Yes | | | |
| Constant | | 8.34** | 2.44 | 14.99*** | 35.46 | | |
| Sigma | | 14.99*** | 35.46 | | | | |
| $Chi^2$ | | 474 | | 299 | | | |

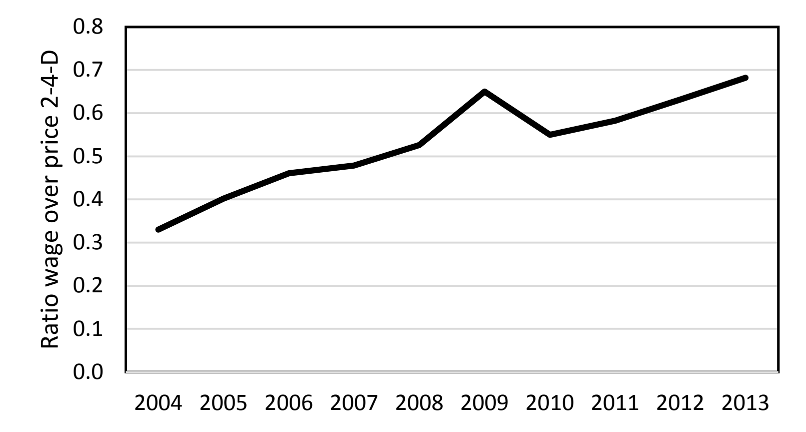
Source: Authors' calculation based on the 2012 teff producers' survey

Note: Observations: 2,397. Coefficients with ***, **, and * are significant at 1, 5, and 10 percent, respectively.

We use a double-hurdle model to more fully explore factors associated with the decision to adopt herbicides and the amount of herbicide applied. Table 7.1 presents the results of the first and the second hurdle regressions. We also report average partial effects (APE) which reflect the total—including both the first and second hurdles—impacts on herbicide use. Looking at the table, several notable patterns emerge. First, transport cost to Addis Ababa is an important associated factor, negatively related with both the decision to use herbicides and the amount used. A lower proportion of farmers in areas farther from Addis Ababa adopt herbicides, and those that adopt in remote areas use relatively less. We find, conditional on purchase, that a doubling in transportation costs to a big city reduces spending on herbicide by more than two Birr per hectare. Distance to nearest agro input-dealer, a measure of input-market access, is also significantly associated with lower adoption. Second, higher rural wage rates significantly increases the likelihood of herbicide adoption. Given adoption, doubling of rural wages lead to increases in expenditure on herbicide by up to ten Birr per hectare. Third, the composition of the household appears to be associated with herbicide adoption and the quantity used. Finally, herbicide adoption is positively associated with land and other assets.

The results in Table 7.1 illustrate, in the case of teff, that market access and wage rates are significantly associated with higher use of herbicides. These factors have shown significant changes over the last decade, which possibly explain the increased adoption of herbicides seen in Ethiopia over this period. Bachewe et al. (2016) have illustrated the extent of the increase of rural wages in the last decade in Ethiopia, showing that real rural wages have increased by over 50 percent overall during the 2004 to 2015 period. To demonstrate how observed changes in real wages may have incentivized herbicides use, we examine ratios of wages over herbicide prices. As we have no retail prices data, 2-4-D prices were calculated using the import data from the Ethiopian Revenues and Customs Authority. CSA collects data on wages of unskilled laborers from 120 markets. We consider average wages in rural areas. Figure 7.2 shows the large changes in the rural wage to herbicide price-ratio over the period considered. The ratio of wages over herbicide price increased by more than 100 percent, from 0.3 to almost 0.7, over the last decade, indicating strong incentives for changes in the use of herbicides compared to wage labor over the period studied.

**Figure 7.2: Ratio of rural real wages to the price of herbicide 2-4-D (2003/04-2013/14)**




Source: Authors' computation using CSA prices

Second, there have been important changes in market access, and especially access to cities, for a significant share of Ethiopian farmers in the last decade. The Ethiopian Government invested heavily in roads over the last two decades. The total length of all-weather surfaced roads tripled in less than 15 years, from an estimated 32,900 km in 2000 to 99,500 km in 2013 (NBE 2014). This type of road development has important effects on the connectivity of agricultural markets in the country. In 1996/97, transportation infrastructure connected Addis Ababa to a limited number of urban markets such as Mekelle, Bahir Dar, Jimma, and Dire Dawa. By 2010/11, secondary cities were linked to each other, and major corridors linking key market centers were fully constructed. While in 1997/98, only 15 percent of the population was within 3 hours of a city with a population of at least 50,000, by 2010/11, this had increased to 47 percent (Kedir et al. 2015). The improved road network has reduced travel times between wholesale markets in the country by an estimated 20 percent. Travel costs have fallen even further, with increased competition and a shift to bigger and cheaper trucks (Minten et al. 2014).

In addition to improved market access and changing incentives, other factors accounting for increased use of herbicides were raised during stakeholder discussions. First, farmers in the major wheat and teff growing areas now rotate their crops in their farming systems to a lesser degree than in the past. This is driven by commercial incentives but also by the increasing availability of herbicides. With increasing mono-cropping, weeds become more prevalent, as rotation in crops has traditionally been a method to control weeds as well as to improve soil fertility. Second, smallholder farmers dominate agricultural land use in Ethiopia, making up 94 percent of total cultivated land in 2013/14.[16] However, the relative importance of commercial farmers is increasing over time: the area cultivated by commercial farms increased from 0.46 million hectares in 2007/08 to 1.0 million hectares in 2013/14. These commercial farms mostly rely on herbicide use for weed management, which leads to higher herbicides imports into the country. Third, mechanization is taking off in some areas of the country - especially in the southeastern part. It is estimated that there are at least 500 combine-harvesters active in the wheat sector. According to key informants, the use of combine-harvesters might contribute to the increasing spread of weeds, given that these combine-harvesters travel large distances and carry weed seeds to new areas. Fourth, as conservation agriculture is being promoted and adopted in some areas of the country, this also leads to a higher use of herbicides in these areas.

## 8. CONCLUSIONS AND IMPLICATIONS

Using a combination of quantitative and qualitative insights from different large-scale household surveys, we explore the increasing use of agro-chemicals, particularly herbicides, among smallholder farmers in Ethiopia, where adoption rates are among the highest in Africa. We find that the adoption and use of herbicides has been increasing rapidly, mostly on commercial cereals. The value of herbicide imports is estimated to have increased four-fold over the last decade. While 2-4-D has been the most widely used herbicide, we now observe greater diversification and adoption of second-generation

[16] Aggregating *belg* (minor cropping season) and *meher* (major cropping season) area and comparing it to area cultivated by commercial farmers, defined as those cultivating more than 25.2 hectares.

herbicides that deal with a wider range of weeds. We also examined the labor productivity effects of herbicide use and the drivers of adoption. Using different analytical methods, we find that overall labor productivity improves because of the adoption of herbicides by between 9 and 18 percent. We further find that increasing wage levels and better market access have led to rapid expansion of herbicide use. It is estimated that 37 percent of farmers in high-potential zones use herbicides and that herbicides were applied on more than a quarter of the cultivated cereal area in the country in 2014/15. This is a surprising development in a country that is characterized by seemingly labor abundant small-scale farming.

These research results have important implications. First, because of herbicide adoption, producers save 50 percent on weeding labor alone. In particular, such developments have important gender implications, given that traditionally women’s contribution in weeding is relatively high. In consequence, we might see improvements in social, health, and economic outcomes that are linked to a relaxation of these agricultural time constraints, e.g. improved childcare practices, increased off-farm income, or increased production of other crops, as more time can be spent by women on those. A further understanding of these linkages would be useful.

Second, proximity to cities and distance to the nearest all-weather road are found to be important determinants of herbicide application. As the government is planning further large-scale investments in road infrastructure and urban development, increased herbicide use will further release labor in rural areas during the weeding period, which will have significant impacts on local labor markets, both in rural and urban areas.

Third, given the rapid increase in herbicide use, local regulatory authorities, such as the Regulatory Directorate at MoANR, have not adjusted to this increase. These agencies seemingly do not yet have adequate capacity and resources at their disposal to ensure proper design and implementation of much needed regulatory policies. More support therefore is required in this area. In this regard, greater attention should be directed towards gathering better evidence on agro-chemical adoption and the impacts of use, as well as gaining a better understanding of the benefits and possible disadvantages of increased agro-chemical use in rural Ethiopian communities in order to enhance and guide policies, regulations, and investments.

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# ANNEX: LICENSING REQUIREMENTS FOR HERBICIDES IMPORTS

New brands of herbicides should be registered with the Ministry of Agriculture and Natural Resource (MoANR) to enable the issuing of an import license into Ethiopia[17]. This process requires any company who wishes to import an herbicide to apply to MoANR to have the product tested and registered. The Ministry then identifies and assigns a research institute to test the product - this is often the Ethiopian Institute of Agricultural Research (EIAR). If EIAR is conducting the test, a Memorandum of Understanding (MOU) will be signed between EIAR and the importing company, and the company provides a sample of about 2 liters (2 kg if powder) for testing. After a fee is paid[18], the work will be assigned to subsidiary research centers (regional branches of EIAR) to conduct the efficacy test following specific guidelines. Once the test results are available, the MoANR will then comprehensively evaluate the applying company's dossier/application, taking into consideration, for example, that the storage requirements are met; that the herbicide is not a danger to human and animal health when handled and applied in accordance with the instructions; and that positive contributions of the product outweigh the risks of use under local socio-economic conditions. If the dossier meets the requirement, MoANR will offer an Import Certificate and the herbicide is considered registered.

There are two registration processes: verification and pre-verification. The verification process is undertaken if the active ingredient of the herbicide to be imported is not new to Ethiopia, i.e. a similar herbicide has been imported before. Verification process tests are undertaken on a single plot using the company's recommended herbicide application rate. This registration process could take between 6 and 12 months and any new herbicide brand name needs to go through this process before it gets registered.

In contrast, the pre-verification process is undertaken if the active ingredient is being imported into Ethiopia for the first time. Unlike the verification process where the test is undertaken in a single wider plot, tests under pre-verification are performed on three plots using varying application rates. The three application rates are: the company's recommended rate, one liter less per hectare than the recommended rate, and one liter more. This pre-verification stage takes between 6 and 12 months. Following these trials, the dose with the best result in terms of weed control is selected. The new sample then goes through a verification process and is tested on a wider area over another 6 to 12 month period. This makes the pre-verification process rather lengthy, i.e. between 12 and 24 months. The registration of an herbicide is valid for five years from the issue date of the Certificate of Registration, with a good chance of renewal, provided that the product criteria specified on registration are maintained.

After the registration license is obtained, a second license is required, a Certificate of Competence, which documents that a given dealer has the necessary qualifications to handle pesticides in the proper manner indicated on the registration certificate. These certificates are required both for importers and distributors. This Certificate of Competence is issued for such activities as: (i) manufacturing and formulation of pesticides; (ii) import and export of pesticides; and (iii) pesticide application services involving fumigation. The prerequisite for the Certificate of Competence is mainly that the dealer should be either a plant science expert or should hire at least one such expert, that they should have proper storage facility, and that any non-importing dealers should have an agreement with an importer (registrant).

[17] According to the Pesticide Registration and Control Proclamation No. 674/2010 (Negarit Gazeta 2010), 'No pesticide shall be registered unless the efficacy, safety and quality is tested under field or laboratory conditions and approved by the Ministry. No person may formulate, manufacture, import, pack, re-pack, label, sell, distribute, store or use a pesticide not registered by the Ministry or contrary to the conditions of its registration'.

[18] Between Birr 30,000 - 36,000 in 2015.

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## About ESSP

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